

DBBC3 – A Full Digital Implementation of the VLBI2010 Backend

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Abstract

The project of the third version of the DBBC backend system implementation is presented. This system is able to fully digitally implement the functionalities required by a complete VLBI2010 backend, including the sky frequency conversion in the entire range 2–14 GHz, so avoiding any need of an analog down-conversion to be used as the pre-processor to a polyphase digital filter bank. The architecture and adopted methods are described.

1. Background

The DBBC development started in 2004. In the preceeding years ad-hoc experiments in the laboratory and with real signals from the sky had demonstrated, after years of speculation, that it would indeed be possible to emulate digitally the entire functionality included in the Mark IV VLBI analog terminal, providing digital conversion of the receiver signal from the start. But there was no straightforward way to implement this process at a reasonable cost, and moreover at that time it was a challenge for the wide band and the high frequencies involved. During the first decade of 2000 with progressive improvements the DBBC project generated an evolution in the input bandwidth up to 8×1 GHz, and in the output data rate up to 32 Gbps. The first version (DBBC1) was a one-to-one replacement of the existing VLBI terminal, while the DBBC2 included additional observing modes that did not exist in the analog backend. This has been further enhanced within VLBI2010 which requires a backend that is able to accomplish the VLBI2010 observing mode, the coming next generation of the geodetic VLBI backend system. The VLBI2010 mode operates within a single wide band ranging between 2 and 14 GHz. Inside this range four 512 or 1024 MHz wide pieces are selected, in both polarizations, to realize a band synthesis translated in a much wider portion of spectrum with respect to the present one. Such a wide portion of input band is also of great interest for astronomy because of the significant increase of sensitivity. Having the chance to process as one piece bands that are much wider than the current bands could then represent an actual quantum leap in the digital radioastronomy data acquisition. The goal is very ambitious and represents, to our knowledge, the first time for such an implementation in radio technology. This is the goal for the DBBC3.

2. DBBC3 Structure

The DBBC3 system needs to meet some mandatory requirements: to be compatible with the existing backends of the previous generations and to be able to realize the new functionality in the very wide band. In order to be compatible with the existing systems, the new hardware needs to be ‘mechanical and level-compatible’. This aspect is useful because existing DBBC terminals in

the field can just be upgraded to meet the new performance standards. Moreover elements of the DBBC3 proper can be adopted in the existing DBBC2 and DBBC2010 to improve the capability with additional functionalities. The much higher performance requires new hardware parts, to be accompanied by new firmware development. The main features of the new system are: a) number of Wide Input IF: 4, b) instantaneous bandwidth in each IF: 14 GHz, c) sampling representation: 8 bit, d) processing capability $N \times 5$ TMACS (multiplication-accumulation per second), with N number of processing nodes, e) output data rate: max 1 Tbps, and f) compatibility with existing DBBC environment.

Figures 1 through 4 represent the main schematic components of the DBBC3: overall architecture, the ADB3 structure, the Core3 structure, and the FILA40G concept.

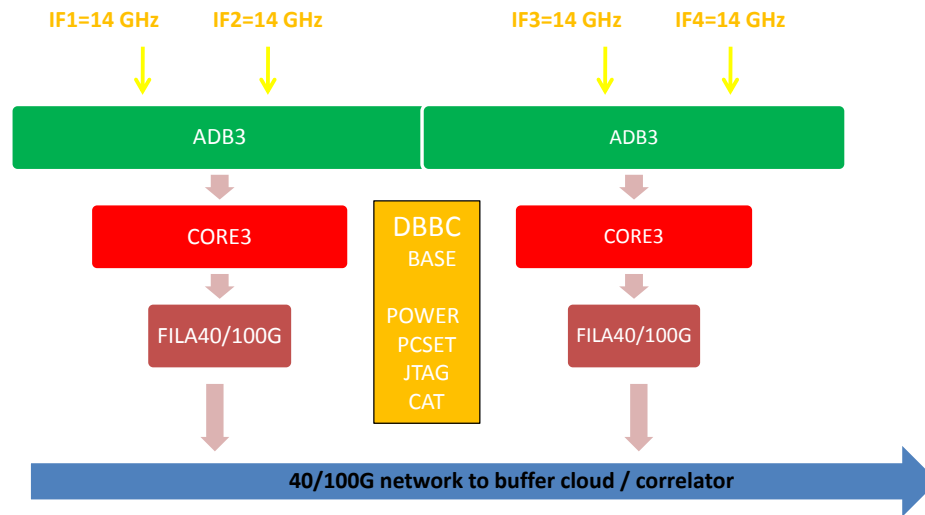


Figure 1. DBBC3 architecture.

The structure of the system is straightforward. Four 14-GHz-wide IFs are sampled with 8-bit representation. The data is then transferred to one or more dedicated processing nodes, with their own single element identity and functionality. The processors then extract in digital format portions of the band (tunable or fixed) and produce output VDIF packets. The last logic element of the chain is the FILA40G whose functionality is to condense in single optical fibers at 40 Gbps data rate and to enable functionalities at the network packet level.

3. ADB3 Sampler

The impressive sampling functionality is performed by a state of the art device at present available in some prototype units. An extensive analysis is under way to determine the phase performance of this device, due to the interferometric use it is called to perform. An alternative general method to improve the bandwidth is to make use of complex samples. Two channels in quadrature are used for sampling at a clock frequency equal to the full instantaneous bandwidth. The device under evaluation to be used for the ADB3 does not require such a solution because it is able to process the entire band in the real domain.

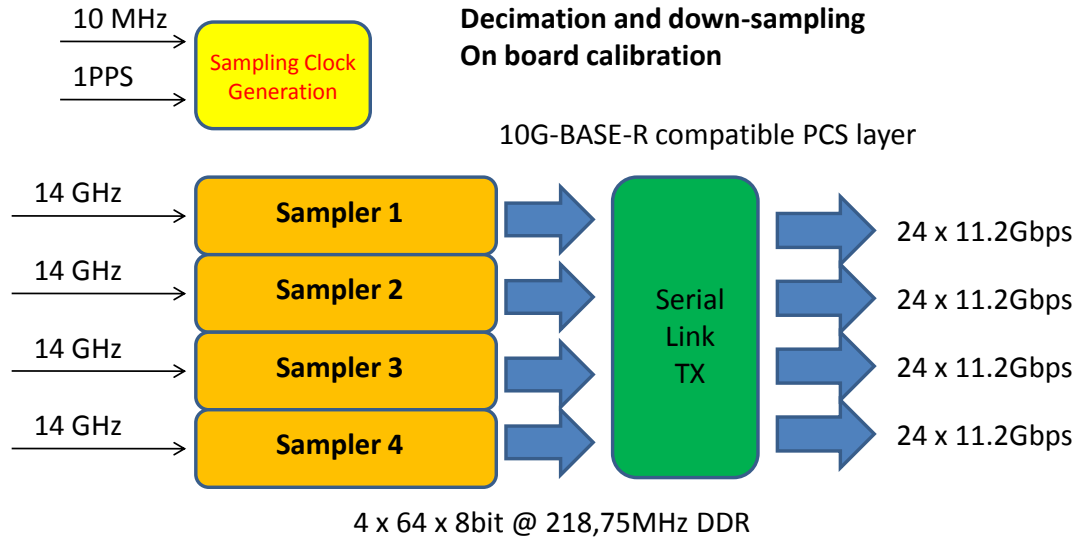


Figure 2. The sampler ADB3.

Sampled data have to be transferred to the next processing stage, and due to the very high data rate (224 Gbps), parallel bus connections are not convenient and perhaps not even possible because of the problems that would occur for the physical connection and the data alignment when operating at so high a data rate. Serial connections linked with dedicated algorithms are then required.

4. CORE3 Processing Node

Data coming from the sampler board ADB3 are routed using the high speed input lanes (HSIL) bus to the processing node CORE3. The board is able to process data in order to realize DDC (Direct Digital Converter) and PFB (Polyphase Filter Bank) functionalities. From the pool of channels the selection is performed in order to accomplish the actual output data rate, through the high speed output lanes (HSOL) bus, allowed by the recording or network media. Additional input and output connections are available to maintain the compatibility with the DBBC stack. The large DSP resources available in the FPGA adopted in the CORE3 give access to digital filters in the class of 100dB in/out band rejection. This feature is required for the large presence of RFI signals in the very wide input band. Such discrimination should be appropriate to obtain useful down-converted and clean (due to the tuning ability) pieces of observed band.

5. FILA40G Network Node

Data from the converted bands are finally transferred to the network controller FILA40G as multiple 10G-like connections. The number of connections is then accumulated in 40GE fashion (perhaps 100G if the technology becomes available) to be transferred to the final destination points. The final points could be more nodes of VLBI correlators as in a buffer cloud. In addition to the 40G network capability the FILA40G unit will be able to manipulate the data packets in order

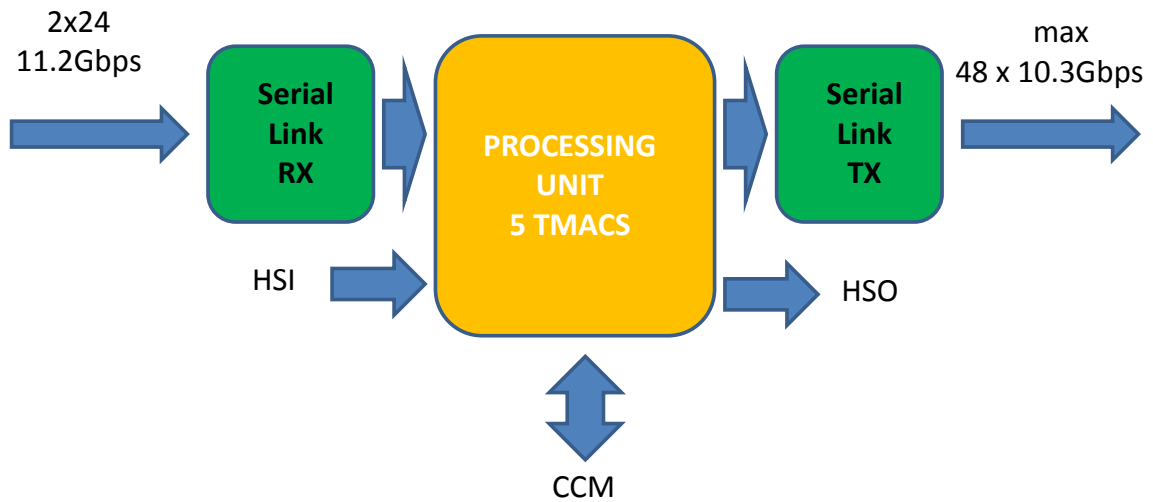


Figure 3. The processing node CORE3.

to perform functionalities like corner-turning, pulsar-gating, packet filtering and routing, burst mode accumulation, and any other functionality that could be required at packet level as soon as the VLBI methods evolve. Additionally it will be possible to include storage elements for data buffering.

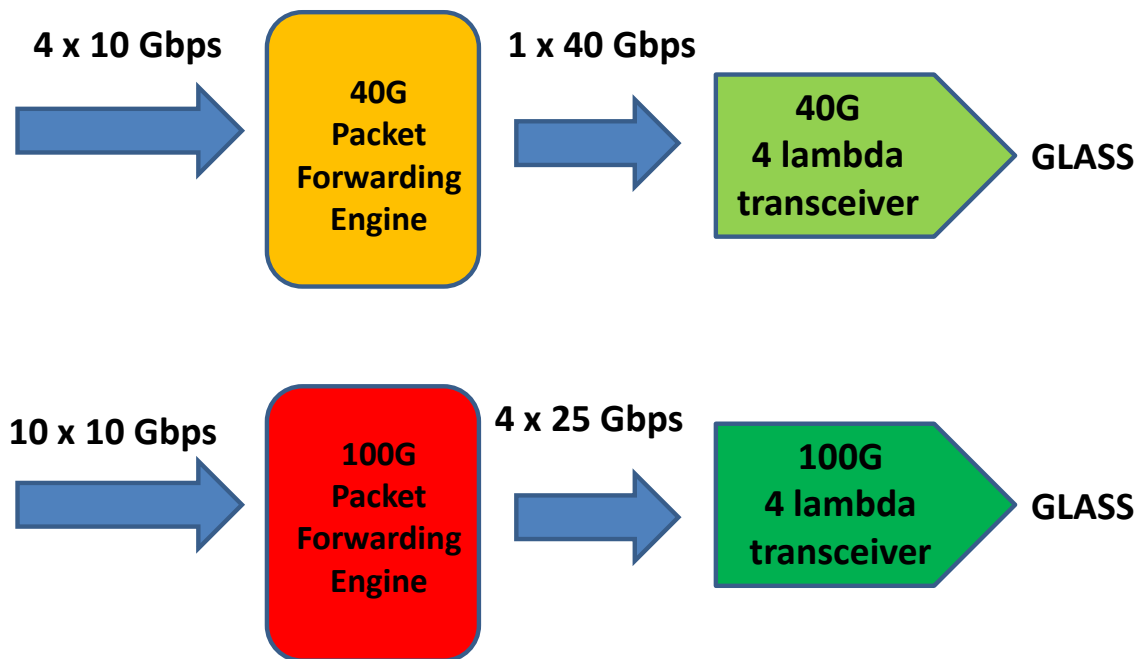


Figure 4. The network node FILA40G.

6. Preliminary Results

Testing and experiments performed with the ADB3 prototypes already available showed that a direct data conversion is possible in the digital domain for the full 14-GHz band, without a need for a preliminary analog conversion. This represents a very challenging and interesting step ahead in the simplification and in the improvement of the VLBI2010 electronics as a significant reduction in the system cost. The term “backend” will not be adequate any longer due to the typical functionality of a front-end that this system would cover. It was possible to perform measurements in different campaigns in 2011 and 2012 adopting the direct acquisitions with a full input bandwidth of 14 GHz. Zero baseline cross-correlations have been realized with samples at the entire 8-bit data representation, coming from two completely independent samplers having only a common low frequency reference clock, both fed with the same signal coming from a noise generator. The results are shown in Figure 5. It can be seen that the amplitude and phase behave pretty well. Phase variations are due only to the wide band splitter used to generate the copy of the input signals, as it was determined by separate measurements.

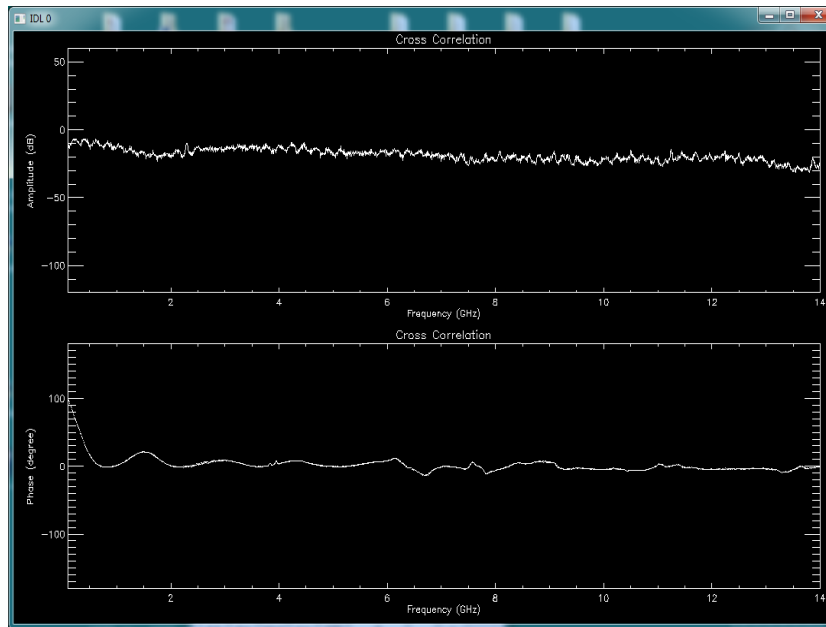


Figure 5. ADB3 preliminary correlation results in zero baseline cross-correlation.

References

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